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SECTION 12

ELECTRIC POWER SYSTEM ECONOMICS

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12.1 INTRODUCTION

The long-range trend for electric supply, demand, and costs are rising erratically and are very volatile as of this writing. The supply is changing due to recent energy deregulation legislation and also due to the rising demands for energy in a global economy of rising fuel prices. The electric demand within the United States is expected to increase dramatically.

The increase is due in part to an expected shift to hybrid or electric cars based on fuel cells, and mass transportation to replace the present fossil fuel based transportation. The need for biofuels and hydrogen fuels in diverse geographic locations will result in new and upgraded electric transmission lines for reliability and transportation of energy.

12-2 SECTION TWELVE

Fuel	Coal	Oil	Natural Gas		Water	Wind Bio-fuels
Transportation	Train Boat Barge Truck	Ship Pipeline	Pipeline LNG—Ship CNG—Ship, train, truck		Water Shed System— River	
Conversion	Electric Generation Plant	Electric Generation Plant	Electric Generation Plant		Electric Generation Plant	Electric Generation Plant
Transportation	Transmission Distribution		Transmission Distribution		Transmission Distribution	Distribution
Customer	Conversion to Heat, Motion, Information					

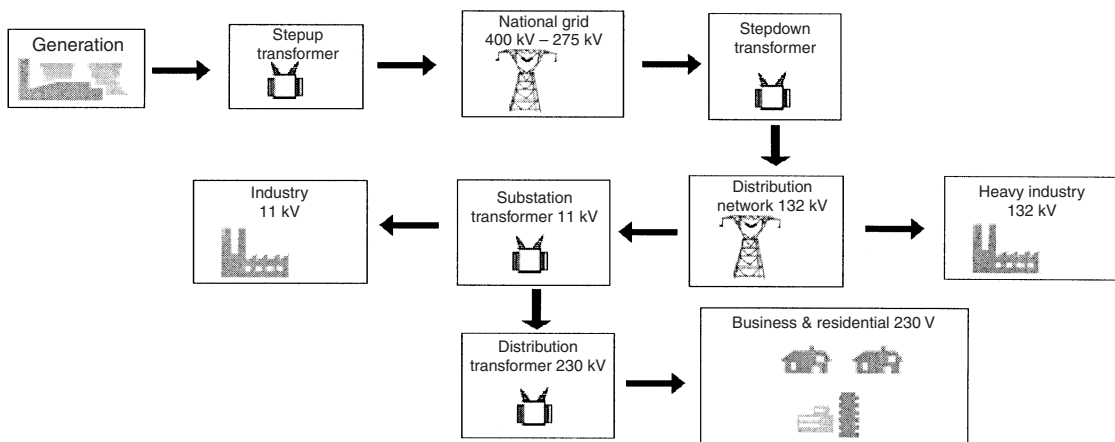
FIGURE 12-1 Leontief model of the energy industry.

A strategic infrastructure for the production and distribution of energy is essential for industrialized nations. The oil crisis of the 1970s, the first oil crisis, demonstrated the dramatic increases in the price of oil and the resulting impact on modern economies of the western nations. The recent dramatic increase in the energy demands of the Asian countries will accelerate and exacerbate these crises.

A Leontief model of the energy industry is shown in Fig. 12-1. Coal was the fuel that industrialized the western countries. Oil and, now, natural gas are sustaining the western economies. Conversion of natural gas to liquid natural gas (LNG) and compressed natural gas (CNG) increases the economy of gas shipment. Hydrogen fuel will most likely start to impact the energy infrastructure in a similar way that LNG has altered the shipment of energy across the oceans. Hydrogen gas will most likely be created and used locally for the most part due to containment problems. Production of hydrogen gas by fuel cells or as a biofuel (bacteria based) is most likely to be a local or distributed process, another distributed generation plant. Hydrogen as a fuel is not yet firmly defined.

Electricity competes with direct use of fuel, such as oil and natural gas, as well as distributed generation based on wind and biofuel-based units. Energy is transported to the point of consumption either directly or primarily by pipeline, or indirectly as electricity.

An electric supply chain model is shown in Fig. 12-2. A traditional natural gas supply chain is shown in Fig. 12-3. An LNG supply chain is depicted in Fig. 12-4. Similar supply chains can be

**FIGURE 12-2** Electric supply chain model.

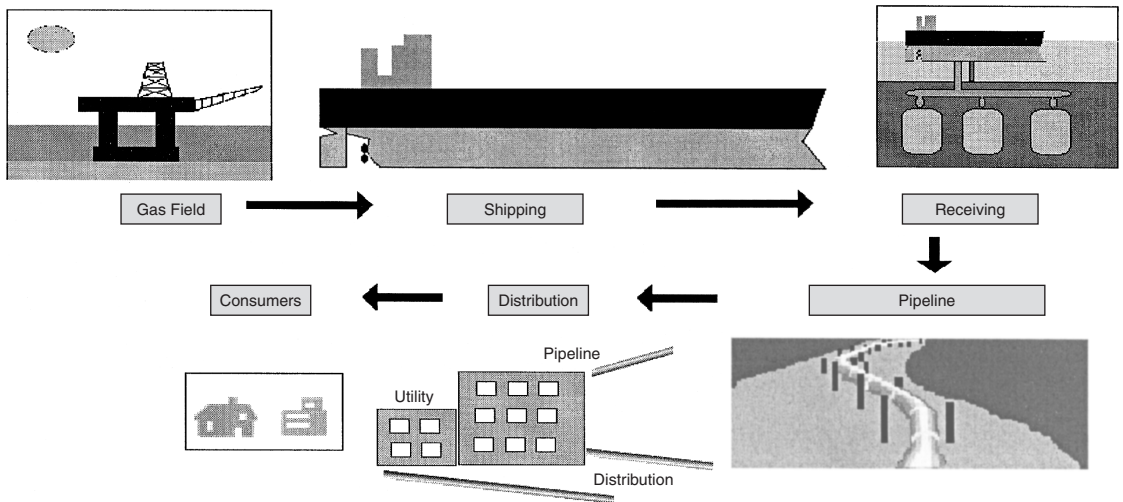


FIGURE 12-3 Natural gas supply chain.

used to depict the use of each type of fuel. Coal, for example, would include track networks for train transportation, river networks for barge transportation, and highway networks for truck transportation.

There is always the comparison of locating a generating plant near a fuel supply and transmitting the power versus locating the generation plant near the load and transporting the fuel. This is the traditional planning problem of comparing the cost of transportation by wire, train, barge, truck, or pipeline. The traditional electric system planning problem was to resolve the more economic and reliable manner of transporting fuel, such as coal, from the mine to the customer. The typical question

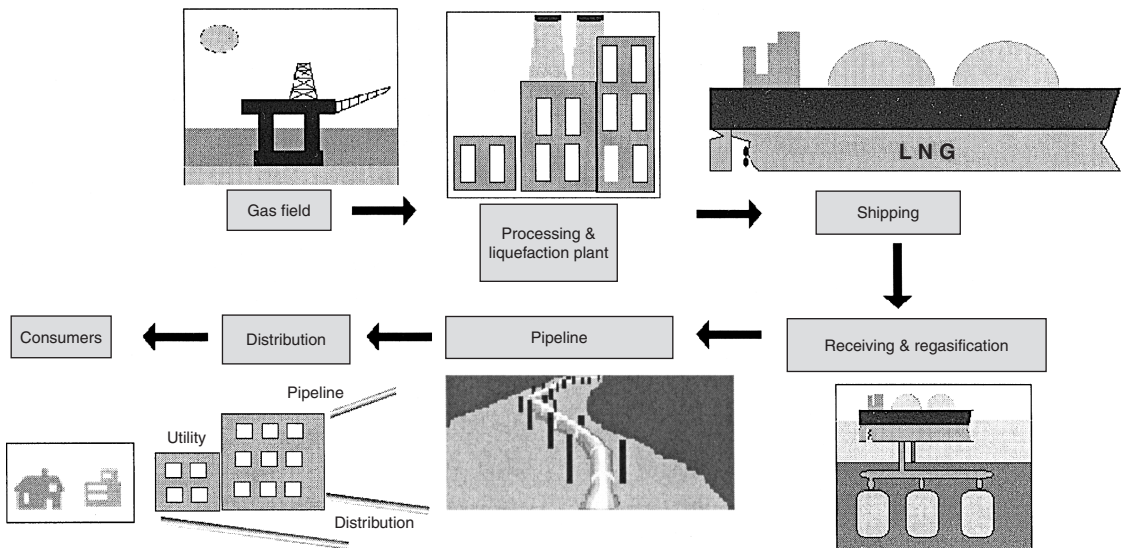


FIGURE 12-4 Liquid natural gas supply chain.

was if the *unit train* of 110 coal cars was more efficient and reliable due to the storage possibilities of coal, than an electric network, highvoltage alternating current (HVAC) or highvoltage direct current (HVDC) systems, to move the energy from the source to the customer.

The expansion of the train network for coal capacity is presently recognized as a constraint on electric system planning as this means of transportation is often congested, and suffers from restricted flows. The same question was posed in the use of oil and natural gas. The expansion of the pipeline networks has leveled the price of oil and natural gas between industrial centers. Thus, there are multiple transportation networks that are operated, maintained, and expanded to move energy from the source to the customer. Each of these networks is an energy grid.

Distributed generation has a compounding impact on the electric transmission system. Distributed generation is composed of natural gas-fired combustion turbines, biofuel-fired combustion turbines, wind generation, solar cells, and recently, gas-fired combined-cycle units consisting of combustion turbines connected directly to boilers, either solely for secondary heat conversion or for additional fuel combustion. Such distributed generation, often called renewable sources, decreases the need for the electric transmission system for basic energy delivery. Instead, the transmission system shifts to a role of providing an alternate energy source when the local distributed generation is not available to provide the desired level of reliability.

The interaction between transmission and distributed generation is complicated by the details of ownership and of interrelated operational responsibility. Many alternative or renewable energy-conversion forms are not expected to be connected to the electric grid but they do considerably alter the use of the energy grids by shifting the demand pattern. Essentially, the interrelationship of alternative resources alters the demand as the customer selects between the competing supply chains.

As a regulated industry, technological improvements reduced the cost of electricity, when all other cost factors were increasing rapidly. The cost of electric energy consists of the total delivered cost from fuel mining, fuel transportation, generation, transmission, and distribution through the supply chain. The generation cost can be broken down into three major components: fuel, equipment, and wages. The relative magnitude of these various components changes primarily in response to fuel cost changes (global economic) and environmental factors, especially due to the environmental impacts, especially as addressed by the Kyoto protocol.

By the late 1980s, the share of the total electric energy cost allocated to fuel costs had increased to 42%. This is equal to the share representing all equipment costs (i.e., generation, transmission, and distribution) at that time. This trend, however, is not expected to continue because of reduced utility dependence on oil as a primary fuel source, and as the LNG supplies increase.

Generating equipment costs have increased more than other equipment costs. In the late 1960s, annual expenditures on construction of generating equipment represented 50% of all utility construction expenditures. This share decreased to 40% by 1989. Generating equipment costs are expected to continue to increase more than other equipment costs, because of the additional costs added to power plants to accommodate environmental and other regulatory requirements. Plant costs have been rising in recent years. Table 12-1 shows average operating expenses from 1992 through 2003.

Distribution costs are determined principally by the population density of the load being served and the geographic characteristics. The shift to buried cable has significantly increased distribution costs in many countries.

Transmission was primarily needed to transport power in a regulated environment. A secondary need was to interconnect for increased reliability. In a competitive environment, more transmission is needed to remove monopoly threats and price manipulation. Transmission costs have always entered into economic comparisons of alternative generation siting. Transmission availability is a major factor when considering alternative-generation contracts in a competitive environment. Transmission limitations and costs have rendered some competitive generation sources beyond the reach of some customers.

Wages represented 26% of the total cost of electric energy in 1968. These costs decreased, compared with other costs during the 1970s. The share represented by the cost attributed to wages was about 18% in the early 1980s. The share today is decreasing as mergers and acquisitions, along with benefit reforms, such as pensions, have reduced the impact of wages for most companies.

TABLE 12-1 Average Operating Expenses for Major U.S. Investor-Owned Electric Utilities

(Miles per Kilowatthour)												
Plant Type	2003	2002	2001	2000	1999	1998	1997	1996	1995	1994	1993	1992
Operation												
Nuclear.....	8.86	8.54	8.30	8.41	8.93	9.98	11.02	9.47	9.43	9.79	10.20	10.43
Fossil Steam.....	2.50	2.54	2.40	2.31	2.21	2.17	2.22	2.25	2.38	2.32	2.37	2.38
Hydroelectric ¹	4.50	5.07	5.79	4.74	4.17	3.85	3.29	3.87	3.69	4.53	3.82	4.33
Gas Turbine and Small Scale ²	2.76	2.72	3.15	4.57	5.16	3.85	4.43	5.08	3.57	4.58	6.47	10.18
Maintenance												
Nuclear.....	5.23	5.04	5.01	4.93	5.13	5.79	6.90	5.68	5.21	5.20	5.73	5.93
Fossil Steam.....	2.73	2.68	2.61	2.45	2.38	2.41	2.43	2.49	2.65	2.82	2.96	2.95
Hydroelectric ¹	3.01	3.58	3.97	2.99	2.60	2.00	2.49	2.08	2.19	2.90	2.65	3.30
Gas Turbine and Small Scale ²	2.26	2.38	3.33	3.50	4.80	3.43	3.43	4.98	4.28	5.39	7.52	12.15
Fuel												
Nuclear.....	4.60	4.60	4.67	4.95	5.17	5.39	5.42	5.50	5.75	5.87	5.88	6.12
Fossil Steam.....	17.35	16.11	18.13	17.69	15.62	15.94	16.80	16.51	16.07	16.67	17.65	17.49
Hydroelectric ¹	--	--	--	--	--	--	--	--	--	--	--	--
Gas Turbine and Small Scale ²	43.91	31.82	43.56	39.19	28.72	23.02	24.94	30.58	20.83	22.19	26.39	28.59
Total												
Nuclear.....	18.69	18.18	17.98	18.28	19.23	21.16	23.33	20.65	20.39	20.86	21.80	22.48
Fossil Steam.....	22.59	21.32	23.14	22.44	20.22	20.52	21.45	21.25	21.11	21.80	22.97	22.83
Hydroelectric ¹	7.51	8.65	9.76	7.73	6.77	5.86	5.78	5.95	5.89	7.43	6.47	7.63
Gas Turbine and Small Scale ²	48.93	36.93	50.04	47.26	38.68	30.30	32.80	40.64	28.67	32.16	40.38	50.92

Two principal economic factors of bulk energy supply are the cost of the equipment and the cost of the fuel. Many combinations of these two have significant energy price impacts. Decisions between existing available and new assets can only be made after estimating all costs, including capital costs, fuel costs, wages, and maintenance costs that occur periodically.

Financial calculations are used to compare the various future scenarios of supplier and buyer interactions. Other environmental and end-use requirements, such as recreation, aesthetics, and health values, have to be included in all economic evaluations.

12.2 PRIMARY SOURCES OF ELECTRIC POWER

12.2.1 General

The primary energy sources for the production of electricity have been based on the combustion of fossil fuels (coal, oil, and natural gas) to produce steam to drive turbines. Alternatively, rivers are impounded to provide water to drive hydraulic turbines. A third principal source is the heat of nuclear reaction by uranium to produce steam to drive steam turbines.

12.2.2 Fossil Fuel Resources

During the early stages of the industrial revolution, most energy was generated by burning wood or coal in a boiler to produce steam to drive reciprocating steam engines, which, in turn, drove machinery by a system of belts and pulleys or was connected to drive wheels for locomotive use. Early electric power generation used the same process except that the belts and pulleys were connected to a generator to produce electricity. A significant advance was the development of the steam turbines.

Multiple units are generally located in one plant in order to achieve economies of scale, as common equipment can then serve more than a single unit. Common equipment includes fuel- and ash-handling equipment, water treatment, support buildings, and computer equipment, electrical equipment inventory for replacement parts, operating and maintenance staff, and transmission-line substation equipment.

Bituminous, subbituminous, and lignite are classifications given to coals to indicate the amount of heat content per measure of weight. Transportation costs are significant and thus lignite, which has the lowest heat content, is often burned only in plants located at the fuel source. Experiments to convert coal to gases have been conducted to reduce the cost of coal transportation and have been implemented with limited success.

Part of the sulfur found in coal is converted to sulfur oxides, which are considered pollutants when discharged into the atmosphere. Most of the eastern and all the midwestern coals have high sulfur content, which requires some form of sulfur-removal equipment. Such equipment significantly increases plant capital costs and reduces plant efficiency. Coals with lower sulfur content are located in some western states. Transportation costs to bring this coal to the East and Middle West add significantly to its cost.

Presently, it is not financially feasible to convert coal to gaseous or liquid fuel, but it is an area of increased research and development. These procedures are attractive because they offer the possibilities of sulfur removal before combustion and of providing fuel for combustion turbines as well as steam boilers.

Boilers and precipitators are designed for the specific heat content, and so and so other physical and chemical properties (like sulfur content) of the fuel need to be used. Rising fuel costs have justified the conversion of many units to the use of multiple fuels.

Biofuels are quickly coming to the forefront as the price of oil escalates. Bio-fuels include ethanol, soy diesel, and gases produced from agricultural sources and animal and human wastes. Recent advances in waste processing have led to the building of power plants in conjunction with waste treatment, especially the waste from animal herds. Plans have been announced to convert human wastes into gases in the near future, partly as a response to reduce the environmental impact of waste-water treatment.

Solid waste is currently being used as a fuel and as an additive to coal in conventional power plants. Such combination fuel burning was in response to landfill limitations, but the increasing cost of oil is starting to justify the active use of waste resources.

Combustion turbines use gaseous and liquid fossil fuels that are burned, such that the hot gases can be used to drive a turbine directly. These combustion turbines eliminate the conversion of energy to steam and subsequent conversion to electricity, and thus have lower costs due to this system reduction. Such combustion turbines are less efficient and require more expensive fuels and more maintenance. The net economic impact is higher operating costs. Recent developments have increased their efficiencies significantly by using the exhaust output of several units as input to a boiler system to create steam as a traditional unit performs. The output of a combustion turbine is a high heat content exhaust gas. Not only is this gas at a high temperature, but it also contains a considerable amount of unburned fuel. It is economically possible to use the exhaust gas to generate steam either directly in a waste-heat recovery boiler or as preheated combustion air into a conventional boiler with the addition of other fuels. The steam produced can then drive a steam turbine-generator.

This arrangement is called a *combined-cycle plant*. Internal combustion engines are used to drive electric generators at distributed sites for reliability of supply. Hospitals, airports, emergency facilities, communication facilities, and other infrastructure needs require distributed generation to achieve significantly increased reliability requirements. Due to the operating costs of such facilities, they do not represent a significant part of total power generation at this time.

Residual fuel oil is a significant source of energy for power production. This oil contains the heavier components of crude oil that remain after gasoline and other light hydrocarbons have been removed. Oil-fired steam power plants are less expensive to build and operate than coal-fired plants. Combustion turbines use lighter oils as fuel.

Natural gas was traditionally a fuel for steam power plants located near oil fields where the gas is produced. The clean burning properties of gas have lead to gas firing in coal or oil boilers in other parts of the country as natural gas pipeline capacity is available. As there is a high value of natural gas for chemical and space-heating uses, its future use as an energy source for electric generation is limited. Natural gas is a significant fuel for distributed generation, especially if the heat can be used locally. Such generation includes combustion turbines that readily use natural gas as a fuel, especially when combined with an additional heat recovery system, called a combined-cycle plant.

12.2.3 Nuclear Fuel

Nuclear reactors were developed as economical electric power production when the long-term storage of the spent nuclear fuel was considered inexpensive. Subsequent studies have led to a mixed conclusion as to whether or not spent fuel can be stored economically over the lifetime of the radioactivity.

No new nuclear units have been built recently in the United States due to the concerns of long-term storage and potential run-away reactions. Many other countries have continued to develop nuclear energy, given the increasing shortage of fossil fuels. The long-term storage of spent fuel continues to be an unsolved problem. Several existing facilities have presently reached the maximum local storage of spent fuel. Additionally, many existing units in the United States are approaching the end of their useful life cycles.

Natural uranium is the basic fuel for all heavy-water fission reactors. It must be enriched (the content of fissionable uranium increased from the natural value of about 0.7% to about 3%) to be usable. This increase is accomplished by passing the natural product through filters or centrifuges that increase the concentration of fissionable material in part of the output while reducing it in the remainder, which is then unusable as fuel. A breeder reactor converts this depleted uranium back into usable fuel, thereby greatly extending the amount of usable uranium.

Plutonium is a fissionable by-product of nuclear reactor operation. It can be mixed into natural or enriched uranium to recover the energy available in the plutonium.

Fusion reactors are expected to use deuterium as fuel. This material exists in large quantities in water but would have to be extracted and converted into a usable form as is presently under investigation as a multinational experiment.

12.2.4 Hydroelectric Power

Natural precipitation as rain or snow provides a continuous source of water at elevations higher than sea level. The flow of water back to lower elevations provides a source of energy by converting the potential energy into kinetic energy using waterwheels. Impoundment of rivers by dams provides a steady energy source and a larger elevation difference to localize the potential energy. The higher elevation of water locally is measured as effective water head. The natural elevation differential Niagara Falls was used for the motive power for the first commercial alternating current (ac) central station.

Hydropower is a renewable fuel resource. However, the traditional harnessing of hydropower is complicated by the need to dedicate a significant part of a river course to form a lake large enough to provide a steady water source. Initial costs for the dam and other construction work are significantly higher than for other types of generation. This higher first cost must be offset by long-time fuel cost savings. Therefore, the justification of hydropower is very sensitive to the replacement of other fuels and the scheduling procedures. Often the cost of a project is divided between multiple uses of water, such as power, navigation, irrigation, recreation, and flood control. These competing uses greatly restrict the availability (and thus the relative cost) of the power.

The use of tidal movement of water to generate power has been proposed in some coastal locations where there are large tides. Because of the relatively low water head provided by tidal action, it was originally thought necessary to impound huge quantities of water. The cost of the impounding structures has been found to be prohibitive. The structures also probably would have a significant environmental impact owing to their great size. A new alternative is to use wind generators to harness the energy in tidal, river, and ocean currents. Such water generators resemble wind generators but are inverted, suspended from the surface, restricted to locational movement by anchors, and spin as the current flows across the blades, roughly at the speed of a revolving door. While navigational use of that immediate area is restricted, the impact is considerably different from conventional hydro facilities. It is expected that the low cost of such systems may revitalize many of the abandoned hydro facilities with low head capability.

Efforts are being made to develop power from ocean-wave action, but these are experimental and have a significant impact on the aesthetic shoreline use.

12-8 SECTION TWELVE**12.2.5 Geothermal Steam**

At several locations in the world, natural steam is close enough to the surface of the earth that is accessible by using conventional drilling methods to pipe it to the surface. These locations are too few to be of any overall significance to most countries. The expansion of the use of geothermal steam to areas where the heat is not near the surface will require major progress in the development of very deep-well drilling technology. There is a considerable cost to the maintenance of such units as the steam has significant quantities of corrosive and solid materials that reduce the life-expectancy of heat transfer equipment. However, the availability of such steam in several locations could be harnessed to generate hydrogen within the near future for export to energy-dependent regions.

12.2.6 Fuel Cells

Fuel cells generate low-level direct-current (dc) power as a result of a chemical reaction between a hydrocarbon fuel and oxygen. Development has progressed to the point where practical devices are available, even with the use of natural gas and other biogases. However, the costs have not yet been reduced to the point where fuel cells can be considered as competitive with other conventional power sources except in special applications where highly reliable power sources are required or in remote locations.

12.2.7 Primary Batteries

Primary batteries use a chemical reaction between two components of the battery to produce dc power. The battery components are depleted up in the process. At present, the cost is prohibitive for large-scale applications.

12.2.8 Solar Electric Power

Electric power can be developed from the sun's rays in two ways: solar cells that produce low levels of dc power as a result of the sun's rays striking certain materials and solar boilers that consist of a system of mirrors that concentrate the rays from a large area onto a vessel containing water. Practical use of solar electric power must overcome two fundamental problems: (1) the sun's energy is so diffuse that very large earth surface areas must be covered by the mechanism used to collect and convert the energy; and (2) practical energy output is limited to part of the daylight hours on cloudless days. The practical locations in the United States are in the southwestern deserts, which are relatively far from power-consuming areas as to require major transmission lines to deliver the power.

The diffuse nature of the sunlight can be harvested by the use of many photovoltaic solar cells located on all homes within a regional area. Several home owners in the southwest part of the United States have invested in such systems as the price of oil has risen significantly. Presently, such installation cost in the range of \$15,000 to \$20,000. The net profit from such installations was demonstrated as \$200 to \$300 per month in 2005. Home owners were pleased with this return on investment while reducing the dependency of the country on oil.

The use of solar collectors to power a conventional boiler have been constructed and demonstrated. Maintenance costs are high as the reflective surfaces are easily contaminated and abraded in such environments. Research into more resistant materials may soon render it possible to justify the conversion of solar energy to steam, solely on the basis of the fuel that is not consumed.

12.2.9 Wind Power

It is practical to generate power from propeller-driven generators. Recent developments in the capability of equipment and the advanced controls to cope with the variable nature of the wind and demand have lead to a major shift to use wind as a primary source of electricity. The European Union and several U.S. investors have committed to major wind development investments. Several European countries have shifted to a high penetration of wind generation, as high as 61% in the Netherlands, due to expected scarcity of fossil fuels in their regions. Costs have been significantly reduced, while the

equipment reliability has been dramatically improved. The use of wind generation is easily justified for remote areas.

12.2.10 Distributed Generation

There are two generic types of distributed generation. Distributed generation is inherent when renewable resources are the fuel, such as biofuels, solar, and wind. Distributed generation is also justified when heat or steam can serve other uses.

Several companies have developed small gas-fired generating units that are intended to be located in small groups scattered throughout the distribution system. The first units were designed to be 50 kW in size. Such systems have been installed and justified when the heat is also used for environmental heating or manufacturing processes. In remote locations where electrical systems do not exist, it is expected that one or two extra units can be installed if biofuels are available. Such systems are used extensively as backup and for unplanned expansion. Many of these are operated as stand-alone systems.

It is necessary to have alternative power sources to supply the load when the sun is not shining, the water flow is reduced in dry season, and the wind is not blowing at the proper speed. These alternative resources include energy storage and demand-side management, as well as the use of conventional power plants. Thus, many of the renewable energy systems (wind, water, biofuels, etc.) require alternative sources, such as conventional power systems, or local storage. Local storage can include heat storage as well as hydrogen-based fuel cells.

There are industrial processes that require large amounts of heat at temperatures and pressures below those at which boilers generate steam. When such combined demands are served by an integrated power plant, it is possible to obtain low-cost power by generating steam at a higher temperature and pressure and running it through a turbine, subsequently exhausting the steam in the condition required by the industrial process. This arrangement for multiple uses is called a cogeneration unit (traditionally called a topping unit) as such a joint service capability provides economical energy for the following reasons:

1. The additional construction cost for the higher-temperature and higher-pressure boiler plant is not significantly higher than the cost of a boiler plant built to supply the industrial process demand only.
2. The required additional fuel generating higher-temperature and higher-pressure steam is less than the fuel cost for generating steam for industrial demand only. One principal reason for this is that for a conventional generating unit, the steam must be condensed back into water to obtain good overall efficiency. The condenser used for this purpose must be supplied with cooling water that absorbs most of the heat in the steam exhausted from the turbine. This heat is then dissipates to the atmosphere. There is far less condenser heat loss because the exhaust steam is used for process heat.
3. Cogeneration units are installed in many facilities requiring high reliability for industrial processes.

Another method of producing by-product power is the use of an extraction turbine, which has openings at one or more points to allow steam to be removed after it has passed partway through the turbine. This steam is at a lower temperature and pressure than the inlet steam and can be used as process steam. As with a topping unit, the extraction steam does not lose heat to a condenser; therefore, its generation efficiency is very high.

12.3 ENERGY STORAGE SYSTEMS

12.3.1 General Aspects

Electric power is a highly perishable commodity. There is no means of storing it directly in an electrical form. Thus, sufficient generating capacity must be constructed to meet the peak load. This expensive capacity is underused during off-peak periods. Energy-storage systems can reduce the overall cost of power by reducing the amount of generating capacity required. The storage system absorbs energy during off-peak periods and delivers it to the load during peak periods. To be economically effective, the storage system's construction cost must be low and its efficiency high.

12-10 SECTION TWELVE**12.3.2 Pumped-Storage Hydro**

Storing energy can be accomplished by using an electric motor-driven pump to raise water from a lower pool to an upper reservoir when the electric load demand is low (at night or on weekends) or when excess generating capacity is available. Later, the same motor pump can be operated in reverse as a turbine-generator using the water in the upper reservoir as an energy source.

For a pumped-storage system to be economically justified, the power-source fuel cost must be very low (hydro, nuclear, high-efficiency fossil, solar), and the construction cost of the pumped-storage plant must be lower than alternative generating capacity. Low construction costs per unit of power require a very large capacity plant and a large elevation difference between the upper and lower pools (doubling the water head cuts the required storage volume in half). There are not many locations where the topography is suitable for this type of installation.

12.3.3 Hydrogen Fuel Cycle

A scheme that has been proposed to store the energy output of low-fuel-cost plants when they are not required to supply load is the hydrogen fuel cycle. The surplus generating capacity would be used to obtain hydrogen from water by electrolysis. The hydrogen would then be stored or transported for use as a fuel in another generating unit. Much development work will be required to determine the overall costs for this system.

12.3.4 Storage Batteries

Practical storage-battery systems are available to store surplus electrical energy in chemical form for use at a later time. However, at the present time, overall cost benefits have not been sufficient to justify the large-scale trial installations that are needed to verify costs and reliability. Research has instead been conducted on fuel cells that serve the equivalent purpose.

12.3.5 Cryogenic Storage Magnets

Research has been conducted on large cryogenic (supercold) magnets that have the capability of storing large amounts of energy in their magnetic field for long periods of time because of the very low electrical losses in the magnet conductors. Much additional research and development are required before the relative economics of this device can be determined.

12.3.6 Flywheels

The use of mechanical flywheels has been proposed for energy storage. Major development of strong materials will have to be made and pilot plants built to demonstrate the reliability and costs for this type of storage before it can be justified. Funding for this research has been reduced.

12.4 DEVELOPMENT OF ELECTRIC POWER SYSTEMS

12.4.1 Need for Fuel, Demand, and Price Forecast

The process of deregulating the electric industry is still very much ongoing. There are still many questions that haven't been answered regarding how the markets should operate and what is an appropriate market design. The instability of some electric markets has affected other industries, such as the fuel industry. As previously stated, the national load decreased after the 1973 oil crisis. With these industries so closely tied together, it has become harder to provide an accurate forecast on load growth. With the fuel markets seeing record high prices, will demand respond to the price hike and drop? To what extent would it drop? Would the drop be temporary? Could this actually

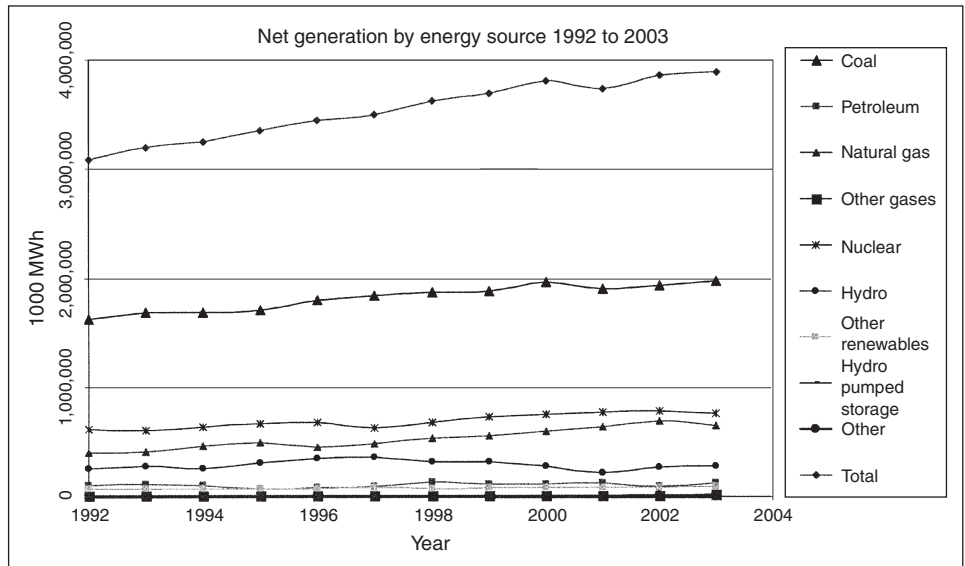


FIGURE 12-5 Net generation by energy source in the U.S.

cause a spike in load growth due to products being switched from fuels to electric loads as we are seeing with hybrid cars? These are all important to understand.

Figure 12-5 shows the net generation in United States from 1992 to 2003 by energy source. The top line is the total generation. Notice that the only decrease in total generation was right after the California market crisis, though the decrease was temporary.

The total net generation has grown just over 2% a year. The fuel types that have the largest growth is natural gas and other (i.e., wind, solar, etc.) with growth rates over 4%. The high growth rate in other, which is mainly renewables like wind and solar, describes the market's concern over the dependency on oil as well as environmental implications. These sources are also becoming more economically justifiable when compared to fossil fuels due to the increase in fossil fuel costs. This concern to invest in energy sources that are more expensive is a sign of how the buyers are beginning to affect the deregulated markets now. Under regulation, there would be no high-price spikes, so assuming the demand to be inelastic was considered not to be an issue.

With the deregulated markets and the frequent market prices, this assumption is becoming more invalid. Though buyers still do not have a direct choice on who they can buy their energy from yet, it is still apparent that the views of the buyers are affecting the markets based on the large growth in renewables. As of right now, the buying side of the electric industry is not deregulated but many support such an idea. If and when that happens, people's preferences as to how their electricity is generated (i.e., environmental impacts) will come into play and those doing the forecasts right now have never dealt with this before; thus, predicting what will happen is a challenge. There is also the suggested market setup where buyers who want better reliability can pay for such and those less dependent on having a reliable connection can pay less. The markets are essentially including more of the buyers' preferences and this will only complicate the forecasting.

Right now most car dealerships have a waiting list for hybrids since they are so popular and this has caused a high demand spike in the industries that create the battery packs. In return, the efficiency in the battery packs is improving due to investment possibilities as well as the costs are decreasing. Figure 12-6 shows the distribution of oil consumption by the different sectors. With transportation being the largest sector and having the highest growth rate, it is easy to understand how even a small conversion from oil to electrical loads can cause predictions to be off.

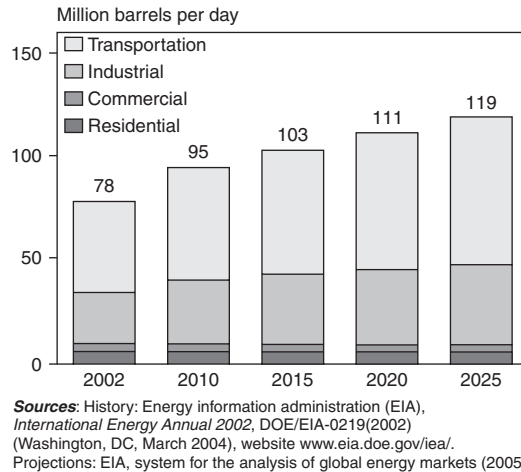


FIGURE 12-6 World oil production by end-use sector.

With the growth of load very dependent on fuel costs, another issue that is arising comes from the emerging economies like China that are greatly increasing their fuel and energy consumption and thus causing a large growth in demand for the entire world. This factor is probably the most influential with regard to load-growth forecasts since predicting what will happen with these foreign countries complicates it immensely instead of just focusing on what is happening within the United States.

It is predicted that the oil consumption in emerging Asia will double between 2002 and 2025. With such strong changes in an industry as this, forecasting becomes very difficult.

Likewise, updating a forecast to be able to account for the exercise of market power is extremely difficult. The Organization of the Petroleum Exporting Countries (OPEC) share of the world oil production market is predicted to increase. Thus, their market power will increase as well. The mature economies are predicted to have very low growth in coal consumption. This reflects the demand side pressure for fuels that are less harmful to the environment.

The cost of fuel is dependent on a lot of variables: supply, demand, market power, etc. There is expected to be a large jump in the petroleum and natural gas markets while the cost of coal is relatively unchanged. The main reason is, though the cost of coal is cheaper, the United States is not investing a lot in coal due to political, environmental impacts, etc.

The demand for oil will increase; however, the price of oil will be more dependent on political, economical, and environmental concerns. These concerns will be the driving forces in determining whether prices will be high or not, since it is predicted that there will not be a problematic scarcity of oil through 2025. These concerns range from the influence governments have on those controlling the markets like OPEC to future environmental laws that might be enacted.

12.4.2 Basic Market Economic Concepts

The major change of industry restructuring is the use of markets to connect the information needs between each link in the supply chain instead of a separate company in a power geographic area. Several markets are implemented to properly price the necessary services to produce and to transport electric energy at an acceptable level of availability. The spot market is for immediate delivery of the commodity. The forward market is for the near-term delivery of the commodity. The future markets are for the financial hedging of the commodity. The bilateral markets include all contracts not traded but executed and committed for commodity delivery. The contingent markets are for

potential trades of a commodity under unusual operating conditions, such as spinning reserves. The option markets include buyer selection contracts that give the right but not the requirement to execute a commodity-exchange contract. Energy balancing and load following markets are used to match the periodic (hourly) energy contracts with the actual instantaneous demand.

A market's basic purpose is to enable buyers and sellers to determine the best allocation of resources which investment is optimal, and so on. Additional commodities, originally organized by the U.S. government, are emission rights that can be traded. Such trading has been a core component of the Kyoto Agreement that is yet to be implemented but has been signed by most of the world governments.

12.4.3 Capital Budgeting Financial Economics

The basic criterion generally used in regulated electric power economic analyses is that the alternative requiring least revenue from the customer is the proper economic choice (Jeynes, 1968). The basis for re-regulated economic analysis is financial analysis as applied to any financial instrument or commodity. The essential process is to determine the costs of investment, costs of operation and of maintenance, and then to compare these costs to the expected revenue over a time horizon. The demand and supply forecasts are discussed in the previous section.

The cost of capital is the major fixed charge associated with an investment, as it is necessary to determine the total payments needed to pay the bonds, financial instruments (mortgage), and stock dividends associated with the investment cost of that equipment. Labor and material cost, including overhead and profit of the supplier (direct construction cost), is easier to track as the facilities are installed. The use of activity-based costs (ABC Accounting) is used extensively to track expenses per task for proper assignment of cost factors.

The cost of fuel includes the price of removing the raw material at the mine or well, processing costs, and the cost of the transportation system (railroad, pipeline, shipping, etc.). Usually, the cost of fuel is reduced to a single figure expressed in dollars per million British thermal units (Btus) as demonstrated by the NYMEX futures contracts. The expense to process and deliver the material is the next cost component to be included. The cost of fuel is priced, based on other fuel market prices due to value of energy selected by the consumer. Increases in the cost of production due to environmental regulations, increases in labor costs, and increases in transportation costs are the components with the largest increases as of this writing.

The amount of fuel in inventory is usually the amount required for 2 or 3 month's operation for each plant. For nuclear fuel, the carrying charges are very high as costs for expended fuel maintenance is increasing as storage costs are clouded by political uncertainty. Generating unit efficiency is stated in terms of the heat content (Btus) required from fuel to produce electric energy (kilowatt-hour). This conversion curve shows the quantity of fuel energy converted to electric energy (Btu/kWh) is called the *heat rate*. The net cost of fuel (dollars/kWh) is the product of the raw-fuel cost (dollars/million Btus) and unit heat rate (Btu/kWh).

Operation and maintenance costs consist of the labor expenses, including overheads for the plant operating and maintenance personnel, and maintenance and operating materials (other than fuel). These costs are modeled as a fixed component (dollars per year) and a variable component that varies with the amount of power produced (dollars/MWh). Since the total of the two is a smaller value compared with ownership and fuel costs, it is common to average the two components into a single figure. A figure of about \$15/kW per year is the median value, with many plants within $\pm 50\%$ of this value and a few beyond that range. Within this wide range there is no correlation with unit size, type (coal, oil, nuclear), or number of units in the plant as the financial economics demonstrate that costs beyond that range are not viable projects.

12.4.4 Financial Engineering Methods of Analysis

Comparison of alternative means of providing power requires combining costs that occur at different times. The cost for constructing a plant occurs over a several-year period prior to initial operation of the facility. Financial analysis is based on the general concepts of capital asset pricing theory,

alternatively, arbitrage–pricing theory. Once the future costs of fuel, construction, operation, and maintenance are forecast, then the demand is forecasted to determine the probabilistic revenue that could be obtained by those assets. The basic consideration is that the expected profit has to be sufficient to pay the risk premium for the expected relative corporate risk.

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